PCT/GB 2003 / 0 0 1 5 9 8
Rec'd PCT/PTO 09 OCT 2004

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

RECD 05 JUN 2003
WIPO PCT

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed *H Behan*

Dated 27 May 2003

Patents Form 1/77

Patents Act 1977
(Rule 16)

THE PATENT OFFICE
28 FEB 2003
RECEIVED BY HAND

The Patent Office

1/77

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP9 1RH

1. Your reference — ABC/21455

2. Patent application number *(The Patent Office will fill in this part)* — 0304667.9

03MAR03 E788222-4 000190
P01/7700 0.00-0304667.9

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

PBT (IP) Limited

1 Astra Centre
Edinburgh Way
Harlow
Essex
CM20 2BN
United Kingdom

Patents ADP number *(if you know it)* — 7645336001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — CONTROL ARRANGEMENT FOR A PIEZO CERAMIC ACTUATOR

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

A A Thornton & Co
235 High Holborn
London
WC1V 7LE

Patents ADP number *(if you know it)* — 75001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	4
Claim *(s)*	1
Abstract	1
Drawing *(s)*	1

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 28 Feb 2003

12. Name and daytime telephone number of person to contact in the United Kingdom

Andrew B Crawford - 020 7405 4044

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

CONTROL ARRANGEMENT FOR A PIEZO CERAMIC ACTUATOR

The present invention relates to piezo ceramic actuators and more particularly to a control arrangement for such an actuator. A piezo ceramic actuator consists of a metal substrate to which a ceramic plate is bonded. A simple and effective actuator is in the form of a planar substrate provided with a slit extending from one edge and parallel to the adjacent edges to form two parallel legs joined by a bight. The ceramic material is then applied to the legs. As is common with most types of actuators, it is necessary that a piezo ceramic actuator operates reliably across a wide temperature range. As a result, metal substrate is manufactured from a carefully selected controlled expansion alloy to ensure optimum thermal stability for the required application. However, the complex thermal behaviour of the piezo ceramic material can often severely limit the performance of the actuator leading to increased cost and complexity as well as reliability issues.

Not only do the basic piezo electric parameters vary with temperature, but a dominant effect is the rapid increase in the histeresis as the temperature reduces. This is especially true for the very active soft ceramic materials used to provide maximum performance from the actuator.

One method for improving performance at lower temperatures is to apply a field to the ceramic material in the opposite direction to the polarisation of the ceramic material. This reduces the remnant polarisation resulting in a significant increase in the working stroke of the actuator and also improves thermal stability. The reverse field, however, must be maintained below the coercive field strength of the material. If the coercive field is exceeded, then rapid reversal of the polarisation direction occurs. This will reverse the direction of movement of the actuator in response to the applied control signal resulting in inverse movement of

the actuator. The correct polarisation can be recovered, but only by exceeding the coercive field, applied this time in the new "reverse" direction.

The coercive field strength is highly temperature dependent, decreasing as the temperature increases to approach 0 at the Curie temperature of the material. Not only does the coercive field vary with temperature, but also the relationship between position and applied charge or voltage is also temperature dependent. This can result in a large variation in speed of response with temperature. This can lead to poor stability in control systems and temperature dependent performance in applications such as piezo speakers where control of the speed of the diaphragm is critical.

The present invention provides a control arrangement for adjusting the control regime of a piezo ceramic actuator in response to temperature variations.

Preferably, the control arrangement incorporates a micro-controller which applies a temperature variable reverse field and charge rate to the actuator. This system substantially improves performance at low temperatures. In fact, the actuator force and deflection increases as the temperature decreases. Using this technique, actuator deflection was found to be improved by a factor of over 3.5 at low temperatures. The range of positions accessible to the actuator across a temperature range is also improved nearly 3-fold. This improves tolerance to variations in position of both the actuator and the mechanism being actuated. This can lead to cost benefits through the use of lower precision manufacturing and assembly techniques.

In order that the present invention be more readily understood, an embodiment thereof will now be described with reference to the accompanying drawings in which:-

Fig 1 shows a block diagram of a control arrangement according to the present invention;

Fig 2 shows a waveform diagram of the high voltage rail during a charge forward/reverse cycle; and

Fig 3 shows a diagram showing the variation of forward and reverse positions of an actuator with temperature.

Referring now to Fig 1, a piezo ceramic actuator 10 is connected to a drive circuit in the form of an H-bridge 11 to which a voltage is supplied from a power supply unit 12. The unit 12 is preferably a variable high voltage source driven from a low voltage source 14 eg 12 volt supply using a controller unit 15. The controller unit 15 also contains an H-bridge control circuit which is connected to the H-bridge 11 and is responsive to signals from a temperature sensor 16 closely associated with the actuator 10.

The H-bridge 11 applies a reverse voltage to the piezo ceramic actuator 10 at constant current. The value of the reverse voltage is controlled by the control circuit in the controller unit 15 in response to signals from the temperature sensor 16. The average charge current is also controlled by the control circuit.

There is a very nearly linear relationship between coercive voltage and temperature in the range -25°C to +25°C as the coercive voltage falls from 270 volts to 80 volts. This is used to apply a very simple algorithm for the control of the reverse voltage. A margin is built in to ensure operation well below the coercive voltage. The forward voltage is maintained at between 400 volts and 500 volts throughout the temperature range. This is shown in Fig 2.

With the above arrangement, an almost constant linear charge rate can be obtained from most of the charge/discharge operation. The benefits of the control system are apparent from Fig 3 which shows the variation in actuator position with temperature under differing conditions. It also shows the actuator positions during the discharge parts of the angle both from a forward position and a reverse position. The discharge from forward position will correspond approximately to

the position reached without reverse biased being applied, ie in “unipolar” mode. It is clear that without reverse bias the performance across the full temperature range is compromised. This is indicated by the different between the arrows a and b.

It will be appreciated that when the above control arrangement is utilised with an actuator whose materials and manufacturing method have been selected in order to provide optimum mechanical thermal expansion properties, considerable advantages can be obtained.

CLAIMS:

1. A control circuit for controlling the operation of a piezo ceramic actuator comprising means for applying a reverse bias voltage to a piezo ceramic actuator, means for generating a control signal indicative of the temperature of the actuator and means for altering the amount of reverse bias voltage as a function of the control signal.

2. A control circuit according to claim 1, wherein the means for applying a reverse bias voltage includes an H-bridge.

3. A piezo ceramic actuator arrangement comprising a piezo ceramic actuator and a control circuit according to claim 1 or 2.

ABSTRACT

A control circuit for controlling the operation of a piezo ceramic actuator comprises means for applying a reverse bias voltage to a piezo ceramic actuator, means for generating a control signal indicative of the temperature of the actuator and means for altering the amount of reverse bias voltage as a function of the control signal.

1/1

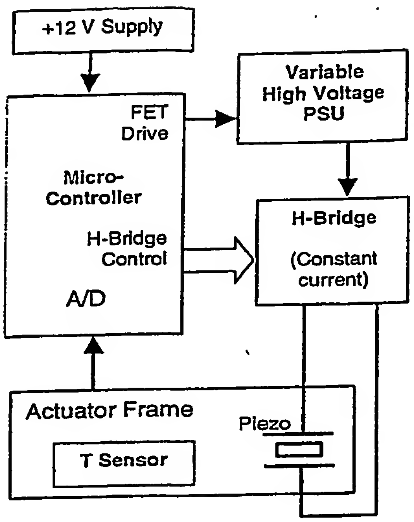

FIG. 1

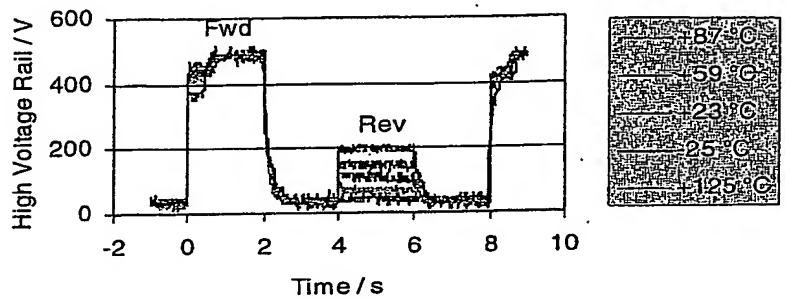

FIG. 2.

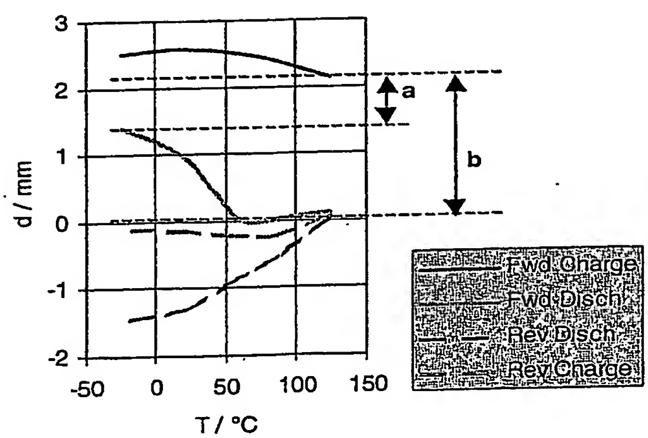

FIG. 3

BEST AVAILABLE COPY